International Journal of Remote Sensing and Earth Sciences Vol.14 No. 2 December 2017: 119 - 126

PRELIMINARY STUDY OF LSU-02 PHOTO DATA APPLICATION TO SUPPORT 3D MODELING OF TSUNAMI DISASTER EVACUATION MAP

Linda Yunita[1], Nurwita Mustika Sari[2], and Dony Kushardono[2]

[1]Physics Department of Universitas Indonesia

[2]Remote Sensing Applications Centre LAPAN

e-mail: linda.yunita@sci.ui.ac.id

Received: 6 November 2017; Revised: 20 November 2017; Approved: 20 December 2017

Abstract. The southern coast of Pacitan Regency is one of the vulnerable areas to the tsunami. Therefore, the map of the vulnerable and safe area from the tsunami disaster is required. Currently, there are many mapping technologies with UAVs used for spatial analysis. One of the UAV technologies which used in this research is LAPAN Surveillance UAV 02 (LSU-02). This study aims to map the evacuation plan area from LSU-02 aerial imagery. Tsunami evacuation area was identified by processing the aerial photo data into orthomosaic and Digital Elevation Model (DEM). The result shows that there are four points identified as the tsunami evacuation plan area. These points are located higher than the surrounding area and are easily accessible.

Keywords: *Aerial remote sensing, photo data of LSU-02, 3D modelling, tsunami*

1 INTRODUCTION

Indonesia is one of the countries located in the Pacific Ring of Fire as well as in between four tectonic plates of the world. This condition makes Indonesia vulnerable to several natural disasters such as earthquakes, tsunami and volcanic eruptions (Siagian *et al.* 2013; Naryanto 2003). Tsunami is one of the natural disasters that have a significant negative impact on the people in the coastal region of Indonesia. Areas along the west coast of Sumatra, southern coast of Java Island to Bali, as well as the coastal areas of Papua and Sulawesi (Sunarto and Marfai 2012). One of the recent examples of the biggest tsunami in Indonesia was the tsunami that occurred in December 2004.

The southern coast of Pacitan regency is one of the areas prone to tsunami. Due to its geographical location, which is near the Indo-Australian plate and Eurasian plates? Based on the USGS earthquake catalog, over the past 100 years, it has been observed that large earthquakes > 7 SR often occur on the seafloor at the depths that are generally less than 30Km. This type of earthquake often found on the epicenter of the Indo-Australian plate that has the potential to generate a tsunami and it is located about 80-100km from the coast of Pacitan. Looking from its distance to the coastline (Islam *et al.* 2014), Pacitan District can be categorized to the vulnerable area of tsunami.

According to Chaeroni *et al.* (2013), the southern region of Pacitan Regency is directly adjacent to the Indian Ocean as well as the ring of fire path because of the convergence of oceanic plates with effort in case of the tsunami. The evacuation map needs to highlight the terrain elevation, which is used to determine the evacuation plan in case of Tsunami disaster.

Developing a tsunami evacuation map requires high-resolution remote sensing data or high-cost field survey data. The limited availability, high cost, as well as high cloud coverage often disrupts the image acquisition. Unmanned Aerial Vehicle (UAV) technology capable of producing detailed spatial data at relatively low cost (Eisenbeiß 2009; Jones 2007). LAPAN has developed unmanned aircraft known as LAPAN Surveillance UAV (LSU) since 2011. At this time LAPAN has several types of LSU, namely LSU-01, LSU-02, LSU-03, LSU-04 and the largest is the LSU-05 which has a wingspan of 5.5 m and capable of flying up to 8 hours with a flying altitude of 3.6 km. Furthermore, LSU-02 is able to fly under clouds for more than two hours and carry out aerial photography missions, resulting in cloud-free images, with detailed and sharper information than satellite imagery, as well as fast and flexible information acquisition (Kushardono 2014; Sari and Kushardono 2014).

Several studies have examined the ability or potential of aerial photography for the use of the identification and interpretation of coastal area objects (Arifin *et al.* 2015), acquisition of remote sensing data with UAVs (Rosaji *et al.* 2013; Kushardono 2014) modeling of 3-dimensional geometry (Gularso 2013), extraction of DEM data (Purwanto 2016), and land cover classification method with UAV (Sari and Kushardono 2014). DEM extraction from satellite data has been derived using various satellite imagery data such as using ALOS, SPOT and ASTER data (Tadono *et al.* 2014; Al-Rousan *et al.* 1997; Kamp *et al.* 2003).

The accuracy of DEM resulting from photo stereo plotting technique from UAV can be quite high, whereby Purwanto (2017) study finds the accuracy of DEM is up to 0.073 m, whereas Uysal *et al.* (2015) obtain a vertical DEM accuracy of 6 cm. A good flight plan that controls the direction of flight and the different altitude (cross flight) of shooting with UAVs can improve the accuracy of acquired DEM (Mark and Heinz-Jürgen 2016). Meanwhile, Matthesen and Schmidt (2016) have proposed the method of making DTM (digital terrain model) from DSM data (digital surface model) of UAV photo data by conducting point cloud filter. However, there is a limited amount of research on the use of DEM and ortho-photo from UAV related to the processing and data analysis for 3D modeling in making tsunami disaster evacuation map. The digital elevation model (DEM) in question is data with raster format that describes the elevation of an area (Siwi 2009). The assessment of the tsunami evacuation area has been conducted for the determination of the tsunami evacuation route by taking into account the nearest distance but not yet at the stage of making evacuation map for tsunami (Madona and Irmansyah 2013; Pratomo and Rudiarto 2013).

This study aims to provide an overview of 3D modeling to create a tsunami disaster evacuation map using the results of processing LSU-02 photo data that has been previously processed into orthomosaic and Digital Elevation Model (DEM).

2 MATERIALS AND METHODOLOGY

2.1 Location and Data

The main data used in this study was the LSU-02 air photo data. The data acquired by LAPAN Aviation Technology Center Tea on April 7th, 2016. The LSU-02 was equipped with a SONY ILCE-6000 camera that flown by 2 lanes along the southern coastal area of Pacitan as shown in Figure 2-1. The average speed of flying LSU-02 during the acquisition was 100 km per hour at 500 m above ground level as well as traveling a range of about 250 km.

Figure 2-1: Flight LSU-02 acquisition of data based on GPS photo results

Figure 2-2: LSU-02 photo data is used

The aerial photographs obtained went as much as 2210 photos with 6000x4000 pixels each and spatial resolution of 10 cm. Front-rear photos overlapped by 80%, while left-right photos overlapped by 60%. Each photo contained coordinate position recorded by the onboard GPS. LSU-02 photo data used in this study located at Watukarung Beach of Pacitan Regency (Figure 2-2) and amounted to 33 photos.

Location data obtained on the field combined with Google map was used as the reference. The GPU specification used in this study was as follows; Core i7 3.40 GHz CPU and 32 Gb RAM. The hardware equipped with data mosaic processing devices, stereoplotting, and data analysis.

2.2 Methods

The data processing conducted in several stages as shown in Figure 2-3. All of the LSU-02 photos were mosaicked and stereo-plotted using the coordinate information stored within each photo. It was then created two products: mosaicked image and DEM. Afterwards, the data were masked to only include the observation target. DEM correction uses field measurement data as the reference. Furthermore, the 3D analysis is derived using corrected DEM data and ortho-image to get the result of disaster evacuation map based on photo interpretation and height of the land.

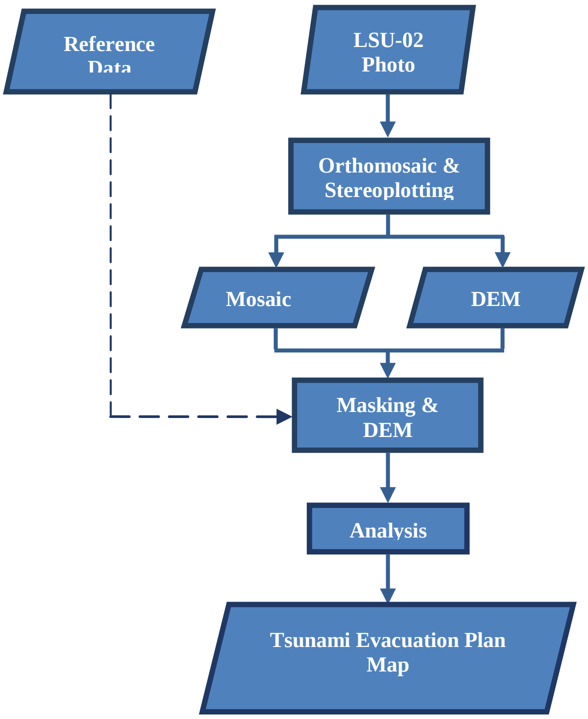

Figure 2-3: Flow of data processing

2.2.1 Mosaic Photo Data

The mosaic process was conducted by combining 33 photo data from the LSU-02. The process begun with Align Photos, followed by Build Dense Cloud, Build Mesh, Build Texture, Build Tiled Model, Build DEM, and Build Orthomosaic. The Align Photos aimed to perform the matching process between the overlapped photos. In addition, Align Photos can also improve the position of the camera for each photo and build a model point dot coordinate system (point cloud model). After the dense point cloud successfully reconstructed, a polygonal mesh model then generated based on the dense cloud data.

Orthomosaic was derived to perform the matching process at the same point on two or more photos. The process was continued by repairing the camera position for each photo and establishing point cloud. Based on the camera position estimation, the program calculated the information from each camera's position to be combined into a dense point cloud that forms the basis for 3D and DEM modelling.

2.2.2 Masking and DEM Correction

The masking process was performed to subset the image only contained the observation area. Afterwards, the DEM value was corrected, using reference data to determine the 0 mdpl value. This process was conducted by taking and calculating the average elevation of some samples taken and creates a linear regression between the DEM and the reference data. Using minimum height value method, the DSM was converted into DTM.

2.2.3 3D Analysis

From the corrected DTM result and orthomosaic images, the 3D model was developed to highlight the relief within the study area. Potential evacuation point was then identified. Nearest highland around the coast identified from DTM data, whereas the least obstacle pathway was identified from orthomosaic images due to its high spatial resolution. The potential obstacle such as buildings and trees as well as the infrastructure critical for an evacuation plan (road, sidewalk) were also identified. These parameters then analyzed to determine the gathering point.

3 RESULTS AND DISCUSSION

Figure 3-1 shows the orthomosaic image created from 33 LSU-02 overlapped photos. Figure 3-1 also shows that the research area is a coastal region. The land cover mainly consists of settlement, forest, and moor. In general, the morphology consists of coastal plains which are dominantly occupied by residential areas, some hilly region around the coastal plains with forest land cover, and bare land on some of the hills.

Figure 3-1: Image of orthomosaic result of study area

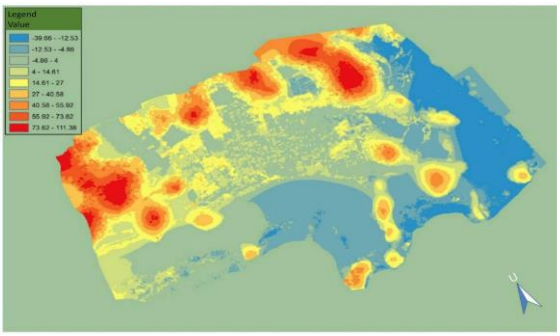

Figure 3-2: The DEM extraction results have been corrected and the contour lines are altitudinal

Figure 3-2 shows the DTM as the product of DEM generation, masking, and elevation correction explained in section 2.2. Elevation correction was performed using field data as the reference. The linear regression analysis, resulted in the linear equation, and the results are as follow:

$$y = 0.2553x + 73.861 \text{ (meters)} \quad R^2 = 0.9413 \qquad (2\text{-}1)$$

The DEM obtained is the Digital Surface Model (DSM). For identification of the evacuation path, the DEM needs to be transformed into a Digital Terrain Model (DTM). By utilizing the minimum elevation value of the transect on the DSM data (assuming the maximum DSM elevation value is the height of the tree or the building above the ground).

Figure 3-2 shows the DTM with the elevation ranging from 0 to 111.38. Based on the image, it appears that the residential area is generally located at an altitude of 0-4 meters. This makes it vulnerable to tsunami threats. The result of previous research indicates that the accuracy of DEM created from UAV with stereoplotting technique reaches 0.073m (Purwanto 2013). This study employed the same technique.

Figure 3-3 visualizes the terrain within the study area. A near-shore residential area on a low coastal plain and a forest on the hill behind have the potential to become the evacuation site in the event of a tsunami disaster. There is also a difference in DSM where tree height and buildings are still visible and flattened to the soil surface at DTM. However, there are slight errors on the seafront that corrected the sea level altitude. This is because the method used is still very simple that based the minimum elevation only.

The 3-D image shown in Figure 3-3 is used to determine the evacuation path to the evacuation point. The DSM data used to identify the effective evacuation path and avoid obstacles such as trees or overly steep slopes. Meanwhile, the DTM was used to assist the creation of an effective path to the evacuation points.

a) 3-Dimensional images of orthomosaic and DSM data

b) 3-Dimensional images of orthomosaic and DTM data

Figure 3-3: 3-Dimensional image of beach Watukarung photos of LSU-02 camera data

Figure 3-4 shows four sites have been identified as the feasible evacuation points. These points located more than 25 meters above sea level. The evacuation route was made from the beach or seafront on the grounds at Watukarung Beach. This is a tourist attraction, so it is likely densely populated by tourists.

The distance between the evacuation points to the seafront are shown in Figure 4-5. Point 1 on Figure 3-4 is located 269 meters from the seafront. Point 2, 3, and 4 are located 360, 343, and 525 meters from the seafront, respectively. But in the implementation, the map of Figure 3-4 shows that in the event of a tsunami, the flow of evacuation can be interchanged, so that people located in area A can reach point 2, the people in area B can reach point 2 or point 3, and the community in area C can go to point 3 or point 4 as an effort to save them from the danger of the tsunami.

Figure 3-5 is also shows the slope for each evacuation point, which appears on the evacuation route to Point 1 of the uphill road, while on the evacuation route to the gathering points 2, 3 and 4 have a similar pattern of land slope through a road that is up to hundreds of meters flat at low altitudes then in the last 30 to 50 meters through a very uphill road. In this preliminary study, the very uphill tracks approaching the gathering point, still need to be studied in more detail to determine alternative paths or made stairs to facilitate climbing to the gathering point above. The most effective evacuation paths are available to each evacuation point for each settlement group in regions A, B and C.

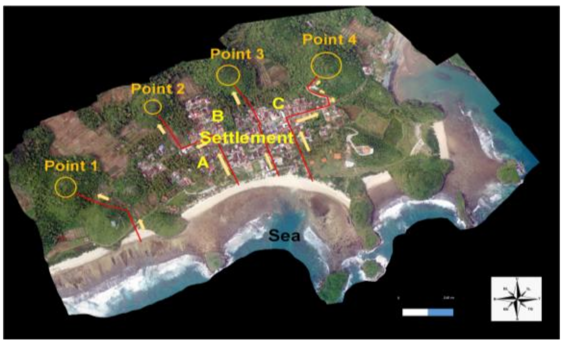

Figure 3-4: The tsunami disaster evacuation map of the research results

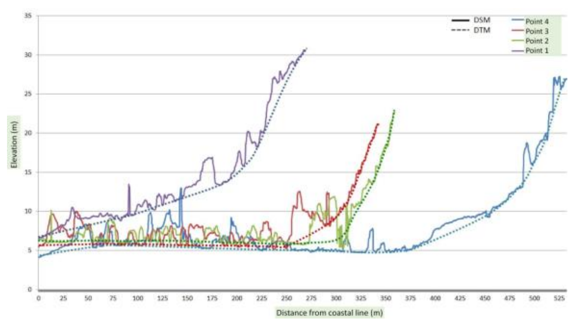

Figure 3-5: Profiles and the distance of each evacuation path to each point of the gathering location and the height of the land

Table 3-1 shows the accuracy assessment for the DEM data created by LSU-02. Fifteen points were created. The elevation for both LSU-02 DEM and the reference data were taken and analyzed. The points represented several types of land cover, from bare land, road and beach area. The highest error was found on point number 5. This point located in the elevated area. The average error was at 1.5 meters. This suggests that in relation to the tsunami disaster evacuation recommendation, errors with these values are still be tolerated, although for the DEM generated from the UAV the error rate is high. However, this is also affected by the accuracy of the reference data used.

Table 3-1: Accuracy assessment of DEM

No.	DEM 9m resolution	DEM LSU-02	Error
1	5	4.1	0.9
2	7	5.4	1.6
3	7	6.2	0.8
4	9	6.8	2.2
5	33	27	6
6	15	14.3	0.7
7	14	11	3
8	12	12.6	0.6
9	11	12	1
10	8	6.9	1.1
11	7	8.3	1.3
12	17	18.44	1.44
13	16	16.7	0.7
14	2	2.33	0.33
15	9	10.5	1.5
Mean ERROR			**1.545**

4 CONCLUSION

This study has shown the potential of LSU-02 aerial photograph data to generate DEM data and high spatial orthomosaic resolution images, from which the DEM data and ortho-images can be utilized for 3D land modeling.

Based on 3D modeling of land and its interpretation, it can be used to determine evacuation points for tsunami disaster, as well as the most effective path to these points.

ACKNOWLEDGEMENTS

The authors would like to thank Aeronautics Technology Centre of LAPAN for the opportunity to use LSU-02 data for this research. We also would like to thank Dr. Adhi Harmoko Saputro S.Si., M.Kom from Physics Department of Universitas Indonesia and Dr. Rokhis Khomarudin as Director of Remote Sensing Applications Centre LAPAN for the support of this research.

REFERENCES

Al-Rousan N., Cheng P., Petrie G., *et al.*, (1997), Automated DEM Extraction and Orthoimage Generation from SPOT Level 1B lmagery. Photogrammetric Engineering & Remote Sensing, Vol 63, No. 8, August 1997, 965-974.

Arifin S., Anas A., Sari NM, *et al.*, (2015), Identifikasi dan Interpretasi Visual Citra Kamera Digital Multispektral untu Obyek Wilayah Pesisir. Seminar Nasional Penginderaan Jauh 2015, 560-566.

Chaeroni Hendriyono W., Kongko W., (2013), Pemodelan Tsunami dan Pembuatan Peta Rendaman untuk Keperluan Mitigasi di Teluk Teleng, Pacitan. Jurnal Penanggulangan Bencana Vol. 4, No.2, 23-33.

Eisenbeiβ H., (2009), UAV Photogrammetry. (Doktor Sains Disertasi), University of Technology Dresden, Zurich. http:// citeseerx.ist.psu.edu/messages/downloads exceeded.html. Accessed August 2017.

Gularso H., Subiyanto S., Sabri, LM, (2013), Tinjauan Pemotretan Udara Format Kecil Menggunakan Pesawat Model Skywalker 1680, Jurnal Geodesi Undip, Vol.2, No.2, 78-94.

Islam F., Subiyanto S., Sabri LM, (2014), Penentuan Resiko dan Kerentanan Tsunami di Kebumen dengan Citra ALOS. Jurnal Geodesi UNDIP Vol. 3, No 1, Tahun 2014, (ISSN: 2337-845X) Pp. 141-154.

Jones BT, (2007), An Evaluation of a Low-Cost UAV Approach to Noxious Weed Mapping. Master Thesis. Department of Geography Brigham Young University, Hawaii. http:// scholarsarchive.byu.edu/cgi/viewcontent.cgi?article=2219&context=etd Accessed August 2017.

Kamp U., Bolch T., Olsenholer J., (2003), DEM Generation from Aster Satellite Data for Geomorphometric Analysis of Cerro Sillajhuay, Chile/Bolivia. ASPRS 2003 Annual Conference Proceedings.

Kushardono D., (2014), Teknologi Akuisisi Data Pesawat Tanpa Awak dan Pemanfaatannya untuk Mendukung Produksi Informasi Penginderaan Jauh. Inderaja, Vol. V, No. 7, 24-31.

Madona E., Irmansyah M., (2013), Aplikasi Metode Nearest Neighbor pada Penentuan Jalur Evakuasi Terpendek untuk Daerah Rawan Gempa dan Tsunami. Jurnal Elektron Vol. 5 No. 2, Edisi Desember 2013.

Markus G., Heinz-Jürgen P., (2016), Accuracy Analysis of Photogrammetric UAV Image Blocks: Influence of Onboard RTK-GNSS and Cross Flight Patterns, Photogrammetrie, Fernerkundung, Geoinformation, vol.1, 17 – 30, DOI: 10.1127/pfg/2016/0284.

Matthesen AW, Schmidt K., (2016), DTM Generation-UAV Point Cloud Classification. Master Thesis, Aalborg University, Denmark. 158p. http://projekter.aau.dk/projekter/files/198676072/SM4_report_DTM_generation.pdf diakses September 2017.

Naryanto HS, (2003), Mitigasi Kawasan Pantai Selatan Kota Bandar Lampung, Provinsi Lampung terhadap Bencana Tsunami. Alami Vol. 8 No. 2 Tahun 2003.

Pratomo RA, Ruadiarto I., (2013), Permodelan Tsunami dan Implikasinya Terhadap

Mitigasi Bencana di Kota Palu. Jurnal Pembangunan Wilayah dan Kota Vol. 9 (2): 174-182 Juni 2013.

Purwanto HT, (2017), Pemanfaatan Foto Udara Format Kecil untuk Ekstraksi Digital Elevation Model dengan Metode Stereoplotting, Majalah Geografi Indonesia, Vol. 31, No.1, 73 – 89.

Rosaji FSC, Handayani W., Nurteisa YT, *et al.*, (2013), Aerial/Terrestrial Videography: Alternatif Teknologi Penginderaan Jauh untuk Survey dan Akuisisi Data Spatial. Prosiding Simposium Nasional Sains Geoinformasi III – 2013, ISBN 978-979-98521-4-4.

Sari NM, Kushardono D., (2014), Klasifikasi Penutup Lahan Berbasis Obyek pada Data Foto UAV untuk Mendukung Penyediaan Informasi Penginderaan Jauh Skala Rinci. Jurnal Penginderaan Jauh Vol.11 No.2, Desember 2014, 114-127.

Siagian TH, Purhadi, Suhartono, *et al.*, (2013), Social Vulnerability to Natural Hazards in Indonesia: Driving Factors and Policy Implications. Natural Hazards, Vol. 69 October 2013 DOI 10.1007/s11069-013-0888-3.

Siwi SE, (2009), Analisis Luas Penutup Lahan Berbasis Citra 2-Dimensi dan 3-Dimensi Studi Kasus: Daerah Tangkapan Air Danau Toba, Pemanfaatan Data Inderaja untuk Pemantauan Sumberdaya Alam dan Lingkungan (pp. 1-13). Jakarta: Massma Publishing.

Sunarto, Marfai MA, (2012), Potensi Bencana Tsunami dan Kesiapsiagaan Masyarakat Menghadapi Bencana Studi Kasus Desa Sumberagung Banyuwangi Jawa Timur. Jurnal Forum Geografi, Vol. 26 No.1, Juli 2012. Universitas Muhammadiyah Surakarta, Surakarta.

Tadono T., Ishida H., Oda F., *et al.*, (2014), Precise Global DEM Generation by ALOS PRISM. ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. II-4, 2014.

Uysal M., Toprak AS, Polat N., (2015), DEM Generation with UAV Photogrammetry and Accuracy Analysis in Sahitler hill, Measurement, Vol. 73, 539-543, DOI: 10.1016/j.measurement.2015.06.010.